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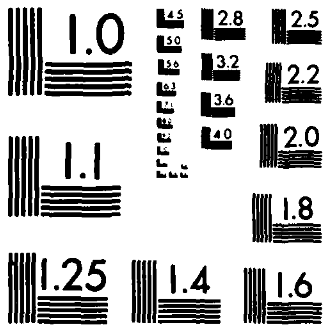

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SPECULATIONS ON THE FUTURE OF TEST DESIGN

Isaac I. Bejar

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Abstract

The paper discusses the potential benefits of integrating technology, cognitive science, and psychometric theory. It is argued that even though adaptive testing, as currently implemented, is an important achievement, it will be necessary to pay close attention to the psychological foundation of tests to continue advancing the state of the art. Such an effort requires construct validation in the broadest sense, as well as focusing on items and why they differ with respect to psychometric parameters, specially difficulty. This approach opens the possibility of generating items with better control of their psychometric characteristics and ultimately the development of computer-based tests that are solidly anchored in psychological theory.

Speculations on the Future of Test Design

Isaac I. Bejar

Introduction

I am grateful for the opportunity to write the final chapter for a book concerned with the improvement of test design. I do not envy for one moment the task of the contributors to this volume, for theirs is a difficult responsibility. By contrast, my task is to speculate on the future of test design, not so difficult a task when, as in this case, the contributors have provided such stimulating descriptions of their research programs.

The chapter is divided in two major sections. In the first section I identify three areas of test design that are bound to be significantly influenced by the increasing availability of technology. These three areas are computer-assisted test assembly, computer-assisted test administration, and computer-assisted test generation. All three will be significantly affected by the sheer presence of technology and thus there is the danger that they may be affected only in superficial ways. Contributions such as the ones presented in this volume will be largely responsible for effecting the hoped-for fundamental change. The second section argues that a fundamental change is more likely to come about by an integration of cognitive psychology and psychometric theory.

Technology and Test Design

Future test designers will have at their disposal the ever-growing fruits of the information revolution. The evidence for this revolution is everywhere, but most significantly it is evidenced by the increasing

presence of microcomputers at school, at home, and at work. For test designers, the increasing availability of technology is a mixed blessing. Although such growth creates the opportunity to develop better tests or administer them more efficiently, it also creates a pressure to computerize tests and use technology superficially. Three areas of test design that are vulnerable to these pressures are

1. Administration of tests by computers,
2. Computer-assisted test assembly,
3. The generation of items by computer.

Administration of Tests

The administration of tests by computers is no longer just a possibility, it is a reality. Moreover, it stands as one of the proudest achievements of psychometrics because the theory that would make adaptive testing a reality, Item Response Theory (IRT; Lord, 1980), was developed before computers were widely available. Had this theory not been developed it is likely that in the current technological revolution computers would have been applied to testing in a shallow manner. That is, computers probably would have used as automated answer sheets rather than as a means of delivering new kinds of tests or more efficient tests.

By the early 1970s computer technology had reached the point where it was possible simultaneously to test several examinees more or less economically. The pioneering efforts of Weiss (1974) capitalized on this event and on the availability of IRT to begin an extensive research program on the psychometric and practical issues of adaptive testing.

In an adaptive test, the computer's job is not merely to present the item and score it but also to determine which item should be administered next, given the student's current level of performance. Although adaptive tests usually use multiple-choice items and thus give the impression that a paper-and-pencil test has been transferred to a computer, in reality different examinees are responding to different tests assembled by the computer for each examinee so that the resulting score may be most precise for an individual test taker.

It is tempting to say that adaptive testing became possible as a result of coupling computers and IRT. The fact is that Binet was doing pretty much the same thing at the turn of this century. Of course, then it was the psychometrician, not the computer, that was selecting and scoring the items. Adaptive testing is thus an efficient implementation of a long-standing idea. Nevertheless, it is still a significant achievement, especially considering what would have happened in the absence of IRT--namely, the blind transfer of items to a computer screen. That achievement is about to become a practical reality. The military and private testing organizations have both been seriously contemplating the practical implementation of adaptive testing systems. In some cases concrete steps have already been taken toward their implementation. Although it is too early to tell what success these initial efforts will encounter, computers are becoming so pervasive that not to give a test by computer may soon appear archaic. Chances are that there will thus be more computer administration of tests, although not necessarily because they are better psychometrically. It will therefore be up to the test designer to make the best possible use of the available technology.

While adaptive testing has been moving forward, technology, psychometrics and substantive theory have not remained static, and the integration of these three opens up additional opportunities. For example, most adaptive testing research has been limited to verbal items. This was so because until recently it was too expensive to display symbols and graphics on a CRT (cathode ray tube). That has changed and in principle test material can even be presented in the form of television images by means of videodisc players. A videodisc permits access to up to 54,000 television frames and, for example, language skills could be tested in very realistic contexts by presenting items as audiovisual sequences. On the psychometric front, models that go beyond the classification of responses into "correct" and "incorrect" have been formulated (e.g., Andersen, 1977; Bock, 1972; Fischer, 1973; Samejima, 1969; 1972; Embretson, Chapter 7, this volume; Scheiblechner, Chapter 8, this volume; Andrich, Chapter 9, this volume) but await tests that make use of their capacity. Finally, on the theoretical side, experimental psychologists have taken seriously Cronbach's exhortation (Cronbach, 1957) to unite experimental and differential psychology. As a result, there have been serious attempts since the 1960s to understand test performance in the light of substantive, not just quantitative, theories (e.g., Carroll, 1976; Embretson, 1983; Lansman, Donaldson, Hunt, & Yantis, 1982). In short, the materials are there not only to improve current practice but also to chart new courses.

<u>Computers and Test Assembly</u>

In the 1960s, one would have predicted that the computer's first inroad into test design would be in assisting with the test development

process rather than in administering tests. As just shown, however, test administration by computer is becoming a reality. By contrast, the possibilities of using computers for test assembly and test creation have hardly been exploited. Before speculating on how test assembly and item generation can benefit from the integration of psychometrics, technology, and psychological theory, I first review the state of the art.

A key problem in test development is maintaining a large item pool from which items may be drawn, according to some set of specifications, to assemble the final form. For the most part, item pools are kept in filing cabinets. When the time comes, however, to assemble another form it might be wise to sweep the floor, because often the test assembler spreads the cards on the floor to select (through an as yet unpublished procedure) a set of items. Typically, the items in the pool have been pretested, a requirement imposed by the actuarial nature of test development. Of course, that is not the end of the process. Once a tentative set of items has been chosen it goes through numerous revision stages in which some items are deleted and still others added. The criteria for reviewing items include the following:

1. Distribution of item statistics such as difficulty and discrimination,
2. distribution of distractors,
3. lexical overlap,
4. conceptual overlap,
5. content classifications,
6. ethnic, racial, and gender bias.

Some of these criteria involve only surface characteristics of the items. Were it not for the fact that items are usually pretested, the test assembler would often have an erroneous idea of the difficulty and discrimination of the item (e.g., Bejar, 1983a). It is in this sense that current test design is an actuarial science. Precisely because tests are assembled on the basis of surface characteristics, the process is amenable to computerization. Such computerization will take place if for no other reason than that it increases productivity.

For example, computers can, to the extent that the item pool permits, assemble a form to meet the requirements just enumerated while simultaneously attempting to meet some psychometric criterion, such as the distribution of item difficulty and discrimination. The ideal system would be flexible enough to accommodate the styles of different test designers, and it would also be interactive. For example, the system should present the test designer with the option of either letting the computer suggest a form or allowing the test designer to assemble a form gradually. In either case the system should be interactive in the sense of allowing the test designer to ascertain how well the design goals have been met as often as the test designer desires. Naturally, the system should be powerful enough to access sizable item pools instantly, regardless of their graphic complexity.

Components of some of these ideas are being contemplated or in some cases have been implemented (e.g., Yen, 1983), but clearly there is room for improvement. For example, while the computer is in the process of selecting a set of items it may easily produce a report on the

availability of different item types for the test designer--who in turn, could take the necessary steps to replenish the item pool following the suggestions of the computer. It is at this point, however, that the actuarial nature of current test design makes itself obvious. If, for example, the computer reports that easy items of a certain category are running out the test designer can, at best, make the arrangements to pretest another batch of items and hope that among them there will be a large number of easy items.

A system to implement these ideas, to my knowledge, has neith been developed nor is it under serious consideration. It is, howe question of time before the economics of the present labor-intensive approach becomes unbearable. Because substantial planning is required to develop such a system, it would be desirable to begin now before the need becomes urgent.

Using the Computer to Generate Items

Computers can be useful for test design because they can advise the test designer about the characteristics of unpretested items and, ultimately, to generate items according to a prescription. These activities would, of course, be much more difficult to achieve; moreover, it would make the system described earlier unnecessary because in generating items the computer would make sure that they meet the required specifications. That is, rather than maintaining large item pools, as is now done, a point may be reached where submitting a prescription for a test to a computer that would produce a test meeting all the content and psychometric specifications would be feasible. Are

we anywhere near the point where such feats are possible? A brief review of the state of the art is very much in order at this juncture.

The essence of the item generation process as it is currently practiced was described by Wesman (1971):

> Item writing is essentially creative--it is an art. Just as there can be no set of formulas for producing a good story or a good painting, so there can be no set of rules that guarantees the production of good test items. Principles can be established and suggestions offered, but it is the writer's judgement in the application--and occasional disregard--of these principles and suggestions that determines whether good items or mediocre ones are produced. Each item, as it is being written, presents new problems and new opportunities. Thus item writing requires an uncommon combination of special abilities and is mastered only through extensive and critically supervised practice. (p. 81)

Chances are good that the state of affairs described by Wesman will prevail in the immediate future. However, some efforts (e.g., Roid & Haladyna, 1982) are under way to make item writing more a science than an art. However, the foundation of many of the procedures outlined in the Roid and Haladyna work rest on a behaviorist foundation, which may make them incompatible with the cognitive turn that psychology and psychometrics have taken. For example, one item generation technique that has evolved is the <u>item form</u> (Hively, 1974). Hively defined an item form as a list of rules for generating a set of items. An item in turn is defined as a "set of instructions telling how to evoke, detect

and score a specific bit of human performance. It must include the directions for (1) presenting the stimuli, (2) recording the response, and (3) deciding whether or not the response is appropriate" (Hively, 1974, p. 8).

From a psychometric and technological standpoint, item forms are attractive. They are congenial test development procedures for psychometric models relying on the assumption that the items in a test are a random sample from some universe of item. Generalizability theory (Brennan, 1983; Cronbach, Gleser, Nanda, & Rajaratnam, 1972) is the most prominent model based on that assumption. From a technological point of view, item forms are also attractive because they permit a computer to generate items. That is, the item form can be viewed as a program that in principle can enumerate all the items that belong to the universe. By the random choice of items from this universe a test can be formed that satisfies the random sampling assumption. Although item forms and generalizability theory are very compatible, the psychometrics of behavioristically oriented test design has often taken the form of very specific models (e.g., Harris, Pastorok, & Wilcox, 1977) rather than the broader foundation provided by generalizability theory.

In short, the closest that has been come to using computers for item generation is through the notion of an item form from which a universe of items can be generated. In my estimation, that approach to item generation is too specialized. In practice, items differ with respect to a number of characteristics, and a useful generation scheme must have control over those characteristics. For example, a useful generation scheme should be able to generate easy items or hard items at

will. I suspect that to build such systems it is first necessary to have an idea of what makes an item easy c hard. Some insights on beginning to do this can be found in efforts concerned with the development of computer programs that take tests (see, e.g., Evans, 1968; Green, 1964; Simon & Siklossy, 1972).

Cognitive Science and Psychometrics

A quick review of the history of psychology (e.g., Boring, 1950) shows that throughout the history there has been a tension between the study of consciousness and the study of behavior. As Boring put it, "in its simplest terms the basic problem about the data of psychology is this: Does psychology deal with the data of consciousness or data of behavior or both?" (Boring, 1950, p. 620). These tensions between opposing views often manifest themselves in psychology, as well as in other sciences, in the form of dichotomies (Newell, 1983). Within psychology behaviorism once dominated the field. The pendulum has now swung and mentalism, in the form of cognitive psychology, now has the upper hand. It seems that psychometrics has swung along with the rest of psychology, as evidenced by the vigor of efforts to cognitivize psychometrics. Some of these efforts are represented in this volume. (The reader is also referred to Embretson, 1983, for an approach that encompasses not only test design, which she calls construct representation, but also an accounting of the relationship among scores from several tests, which she calls nomothetic span.)

It is not necessary to feel sorry for the behaviorist. When behaviorism was champion, psychometricians of that persuasion had their

day, as demonstrated by the following excerpt from Osburn (1968) regarding test design.

> Few measurement specialists would quarrel with the premise that the fundamental objective of achievement testing is generalization. Yet the fact is that current procedures for the construction of achievement tests do not provide an unambiguous basis for generalization to a well defined universe of content. At worst, achievement tests consist of arbitrary collections of items thrown together in a haphazard manner. At best, such tests consist of items judged by subject matter experts to be relevant to and representative of some incompletely defined universe of content. In neither case can it be said that there is an unambiguous basis for generalization. This is because the method of generating items and the criteria for the inclusion of items in the test cannot be stated in operational terms.
>
> The time-honored way out of this dilemma has been to resort to statistical and mathematical strategies in an attempt to generalize beyond the arbitrary collection of items in the test. By far the most popular of these strategies has been to invoke the concept of a latent variable--an underlying continuum which represents a hypothetical dimension of skill. (p. 95)

The notion of criterion-referenced tests was popularized by Glaser and Nitko (1971) shortly thereafter, and for over a decade criterion-referenced tests enjoyed the endorsement of many psychometricians and

clearly had an impact on test design (see Shoemaker, 1975). It is perhaps no coincidence that critics, once behaviorism ceased to be a major influence in psychology, began finding all sorts of problems in criterion-referenced tests. For example, Johnson and Pearson (1975) criticized criterion-referenced reading tests as being linguistically naive. They argued that by focusing exclusively on observable interpretations the usefulness of measuring instruments is diminished. Moreover, advocates of criterion-referenced measurement (e.g., Hambleton, Swaminathan, Algina, & Coulson, 1978; Nitko, 1980) have begun to accept construct validation as playing a useful role in the validation of criterion-referenced tests. This of course implies their acceptance of the legitimacy of using nonobservable constructs in test interpretation. Indeed, there is no reason why an emphasis on behavior and cognition cannot coexist in both an instructional and a psychometric sense (Greeno, 1978).

The more recent emphasis on cognitive psychology has at least two implications for psychometrics. One is the possibility of understanding test performance in terms of cognitive constructs (e.g., Sternberg, 1981). The other possibility is the exploitation of cognitive theory for the improvement and design of both currrent and fundamentally new tests. In the next section I discuss both possibilities.

Validation of Test Performance

The most likely immediate influence of cognitive science on psychometrics is as a source of constructs to validate test scores. Messick (1975) has eloquently argued for the necessity of construct

validation, and the case need not be repeated here. It is sufficient to say that the availability of cognitive or information-processing constructs and the revival of construct validation have important implications for test design.

The validation of both aptitude and achievement tests has relied very little on cognitive constructs. In the recent past validation of achievement tests was strongly influenced by content considerations. This was in line with the behavioristic orientation of criterion-referenced testing that has dominated much of the thinking in the field. Similarly, the validation of aptitude tests, from the Scholastic Aptitude Test (SAT) to the Armed Services Vocational and Aptitude Battery (ASVAB) has relied almost exclusively on predictive validity, and this paradigm is responsible for the psychometric nature of procedures for improving validity. The alternative view is that understanding the nature of the relationship, as opposed to just its magnitude, puts test developers in a better position to increase validity. However, validation based on cognitive constructs, and for that matter tests developed from scratch based on cognitive theory, need not necessarily yield higher predictive validities. It is known from psychometric theory that the magnitude of correlation between a test and a criterion is determined by the proportion of variance in common between the two. Clearly, the test designer has control over the composition of the test but not over the composition of the criterion. Hunt (1983) anticipated this when he noted the following:

> The cognitive science view may lead to the development of new tests that are more firmly linked to a theory of cognition than are present tests. Such tests are yet to be written.

> There is no compelling reason to believe that new tests will be better predictors of those criteria that are predicted by today's tests. After all the present tests are the results of an extensive search for instruments that meet the pragmatic criterion of prediction. Theoretically based tests may expand the range of cognitive functions that are evaluated and certainly should make better contact with our theories of cognition. Theoretical interpretation, alone, is not a sufficient reason for using a test. *A test that is used to make social decisions must meet traditional psychometric criteria for reliability and validity* [italics added]. No small effort will be required to construct tests that meet both theoretical and pragmatic standards. The effort is justified, for our methods of assessing cognition ought to flow from our theories about the process of thinking. (p. 146)

Moreover, from a social perspective, validation solely in terms of predictive validity is inadequate. A predictive validation strategy may have been appropriate when the primary object of testing was the identification of high-scoring individuals, but society's concern with equality requires a focus on low-scoring individuals also. As noted by the Committee on Ability Testing of the National Research Council:

> The relationship between problem solving on tests and everyday performance has taken on new relevance to public policy, as attention has come to focus. . . not on those selected, as was the case when tests were perceived primarily as identifying

> excellence, but on those not selected. This shift in focus has brought new prominence to the question of what is being measured by a given test or item type and has pointed up insufficiencies from a public perspective in validation strategies based solely on the demonstration of external statistical relationships. (Wigdor & Warner, 1982, p. 215)

This quotation and much of the litigation involving tests suggest that in the years ahead test designers will have to be more sensitive to the ethical implications of testing instruments. That is, test designers will have to take into account not just the psychometric and substantive base of tests but their consequences as well. Messick (1980) has suggested that the consequences of testing should be a component of the validation process rather than an afterthought. Just as construct validation consists of collecting evidence from many substantive perspectives, the procedure for incorporating consequences into the validation process consists of collecting information on the implications of using a test in a particular situation. However, such listing of implications cannot be fruitfully done in a psychometric vacuum:

> Appraising the possible consequences of test use is not a trivial process under any circumstances, but it is virtually impossible in the absence of construct validity information about the meaning and nature of test scores. Just as the construct network of nomological implications provided a rational basis for hypothesizing potential relationships to criteria, so it also provides a rational

basis for hypothesizing potential outcomes and for anticipating possible side effects. (Messick, 1980, p. 15)

An Illustration

An example of construct validation in the context of an adaptive test is provided by Bejar and Weiss (1978). They postulated a nomological net to account for achievement in a college biology course and proceeded to test its feasibility with a structural equation model (see Bentler, 1978, for a discussion of construct validation by means of structural equation models). The net is seen in Fig. 1. The rectangles represent the constructs postulated to account for the relationships among the six observable variables. The coefficients next to the arrows are those that need to be estimated. The direction of the arrow indicates that the variable at the head of the arrow is regressed on the variable at the other end of the arrow. Bejar and Weiss concluded that the postulated model indeed fitted the data and that although there were no major differences between the validity of paper-and-pencil and adaptive versions of the test, the adaptive test required 25% fewer items. At the time, such a reduction in the number of items, compared to the cost of an adaptive test, may not have been cost-effective. By the 1980s, of course, the hardware cost per terminal could have easily been less than $1,000, and the economics of adaptive testing may thus appear more attractive.

(Insert Figure 1 about here)

The net postulated by Bejar and Weiss was dictated more by the availability of scores than by an information-processing model of achievement. If measures inspired by cognitive science had been

available they could easily have been used. Rose (1980), for example, developed a battery of tasks that are indicators of information processes. The use of that battery in the validation of the adaptive biology achievement test would have been consistent both with what has been called a cognitive correlates and cognitive components approach to cognitive psychometrics (see Pellegrino & Glaser, 1979; Sternberg, 1981). In the cognitive correlates approach, the goal is to test subjects on several low-level tasks that are believed to be indicative of the subjects' efficiency in processing information. An example of a low-level task is matching whether two letters, such as Cc, constitute a physical match or, as in this case, a name match. Because the tasks are easy, response latency, rather than correctness, is the outcome of interest on such tasks. In a cognitive components approach, the aim is to postulate a model of information processing and to test by obtaining data on the performance of subjects on testlike tasks. The outcomes from either approach can be used as part of a construct validation study designed to gain further understanding of the performance of students in a test.

Although it is beyond the scope of this chapter to consider achievement testing in detail (see Bejar, 1983b), it should be noted that performance on an achievement test depends on both processing components and the storing of information. The cognitive components and correlates approach emphasizes the processing part but not the storage part, that is, the schema for representing information. Other researchers (e.g., Burton, 1982) have emphasized the storage part by elaborating constructs about how the students represent knowledge.

The Bejar and Weiss (1978) study, in addition to illustrating what Messick (1980) has called evidential component of validation, also

illustrated the consequential aspect of validation. Bejar and Weiss found evidence in their data of a medium effect. That is, it seemed that the medium of administration, whether it was paper and pencil or computerization, influenced the scores to some extent. If this medium effect can be replicated, the possible ethical consequences will be something for future test designers to worry about. For example, students from less-affluent homes are less likely to have been exposed to keyboards and CRTs and thus may obtain lower scores. Because these students are also likely to have been exposed to a less-adequate educational environment, it would add insult to injury to test those students by computer without first ensuring that they are at ease with the computer as a medium for test delivery. The work of Snow and Peterson (Chapter 5 in this volume) has obvious implications for research on the detection of such problems.

Towards Scientifically Based Test Design

In the previous section I discussed construct validation as a means to a better understanding of test scores. Although, no doubt, such information could be useful to a test developer, he or she may be at a loss on how to incorporate that information in the creation of new items or of entirely new tests. In this section I argue that from a test design perspective it is necessary to shift the focus of attention from the examinee to the item. That is, just as construct validation of test scores entails research to understand differences among examinees, construct validation applied to test design entails research to understand differences among items. More concretely, it is necessary to

account for the differences among items with respect to their characteristics, especially difficulty. I suggest that cognitive science is an important source of ideas for accomplishing that goal. This integration of psychometric models and cognitive science, as reflected in the work of Embretson (1983) and Fischer (1973), is important not only for advancing the scientific status of psychometric instruments but also for creatively incorporating technological advances into the testing process. For example, if test developers are able to account for differences among items they may have captured the knowledge necessary to synthesize items of known characteristics (see Egan, 1979). They may, in short, be able to write a computer program capable of composing an item with known psychometric characteristics. The chapters by Sternberg and McNamara (Chapter 2), Pellegrino, Mumaw, and Cantoni (Chapter 3), and Butterfield, Nielsen, Tangen, and Richardson (Chapter 4) in this volume provide a basis for research toward that goal.

I would be the first to agree that synthesizing items is not likely to be easy and that sustained research is required before practical results will be available. Nevertheless, adopting that effort as a goal puts test developers in the enviable position of simultaneously pursuing scientific and economic goals. That is, the ability to synthesize items is likely to improve the productivity of the test designer in much the same way that computers have altered the productivity of, for example, graphics designers in various industries. To reach that point, however, they will have to do considerable work to establish and validate a theory that explains the characteristics of items.

It is beyond the scope of this chapter to outline a detailed research program that will in the end allow the synthesis of items.

However, a natural starting point is to account for the variability among existing items. (See Carroll, 1979 for an attempt to do so.) Unfortunately, this task is made difficult by the fact that most existing tests are of the multiple-choice variety. No doubt with such items the context in which the correct alternative occurs partially determines the psychometric characteristics of the item. This, unfortunately, makes the task more difficult than it ought to be because the multiple-choice item was invented to facilitate group testing, and thus its usefulness will presumably diminish as computers are used more and more in the administration of individualized tests. In the meantime, however, test designers must be ready to deal with the complications introduced by multiple-choice items.

Psycholinguistic theory is a rich source of hypotheses for the study of verbal tests such as reading comprehension tests and writing ability tests. Psychologists have devoted considerable attention to sentence comprehension (e.g., Kintsch, 1977). One early theory was postulated by Miller (Miller & McKeon, 1964) and is known as the Derivational Complexity Theory. According to this theory the comprehensibility of a sentence is determined by the syntactic complexity of the sentence. Complexity was measured as the number of transformations required to go from the deep structure to the surface structure of a sentence. Although this particular theory is not now well supported, it seems reasonable to suggest that if comprehensibility of a sentence is affected by some measure of syntactic and semantic complexity then psychometric difficulty of an item based on that sentence will to some extent also depend on the syntactic and semantic complexity of the sentence.

A test with items based on sentences is the Test of Standard Written English (TSWE), sponsored by the College Board and produced by the Educational Testing Service. One of the two item types in the test consists of a sentence that may or may not contain a grammatical error. The examinee's task is to determine whether the sentence as it stands contains an error; if it does, the examinee must select from several alternatives to correct the sentence. One way to apply these ideas to the TSWE is to obtain several measures of linguistic complexity on each item and study the relationship of those measures to psychometric difficulty. If a stable relationship is found, then, in principle, the resulting model may be used to predict the difficulties of new items and even to modify items so they will be easier or harder.

Although the preceding remarks are speculative, some research along these lines already exists. For example, the Degrees of Reading Power (DRP) sponsored by the College Board, is a reading comprehension cloze test. Unlike the usual cloze test, the DRP is a multiple-choice test; that is, the examinee is provided several choices for filling in the deleted word. The difficulty of those items can apparently be predicted on the basis of the readability index of the passage. Similarly, Swinton (personal communication) has experimented with verbal analogy items by forming different versions of the item in order to alter their difficulty.

The idea of synthesizing items of known characteristics has been implemented by at least one research team (Burton, 1982). They were concerned with the design of diagnostic tests of subtraction. Their

goal was to infer what misconceptions may account for a student's error in arithmetic. To speed that process up it is necessary to synthesize items "on the fly" that are most informative with respect to the current set of hypothesized misconceptions. That is, a computer creates the items as they are needed rather than retrieving them from a pool.

One area that seems ready for the integration of cognitive theory and psychometric models is spatial ability. Spatial ability has been a subject of intense investigation. A well-established finding is that the response latency to problems that require mental manipulation is a function of the physical characteristics of the test stimuli. For example, the time it takes to determine whether two geometric figures are the same is a linear function of their angular disparity (see Cooper, 1980). This finding suggests that the psychometric difficulty of spatial items could be predicted from an analysis of their physical characteristics. A project investigating this possibility is under way at Educational Testing Service under the sponsorship of the Office of Naval Research.

Concluding Comments

In this chapter I have attempted to enumerate some of the ways in which the integration of technology, cognitive science, and psychometric theory can benefit test design. The state of the art is most advanced with respect to the administration of tests, with the notion of adaptive tests rapidly approaching operational implementation. As I have suggested, adaptive testing is a significant step forward. However, from a user's point of view, an adaptive test is just a multiple-choice

test administered by computer because the improvements in efficiency and even the test's psychological advantages are not obvious to the naked eye.

I have argued that to move the state of the art forward it will be necessary to pay closer attention to the psychological foundation of tests. This effort calls, on one hand, for the construct validation of tests from both an evidential and consequential perspective. On the other hand, I have also argued that to improve the scientific basis of test design it is necessary to focus attention not only on variability among examinees but also on variability among items. In particular, a better understanding of why items behave the way they do is needed. From a practical perspective the payoff for doing so will be the possibility of ultimately being able to synthesize items of known psychometric characteristics.

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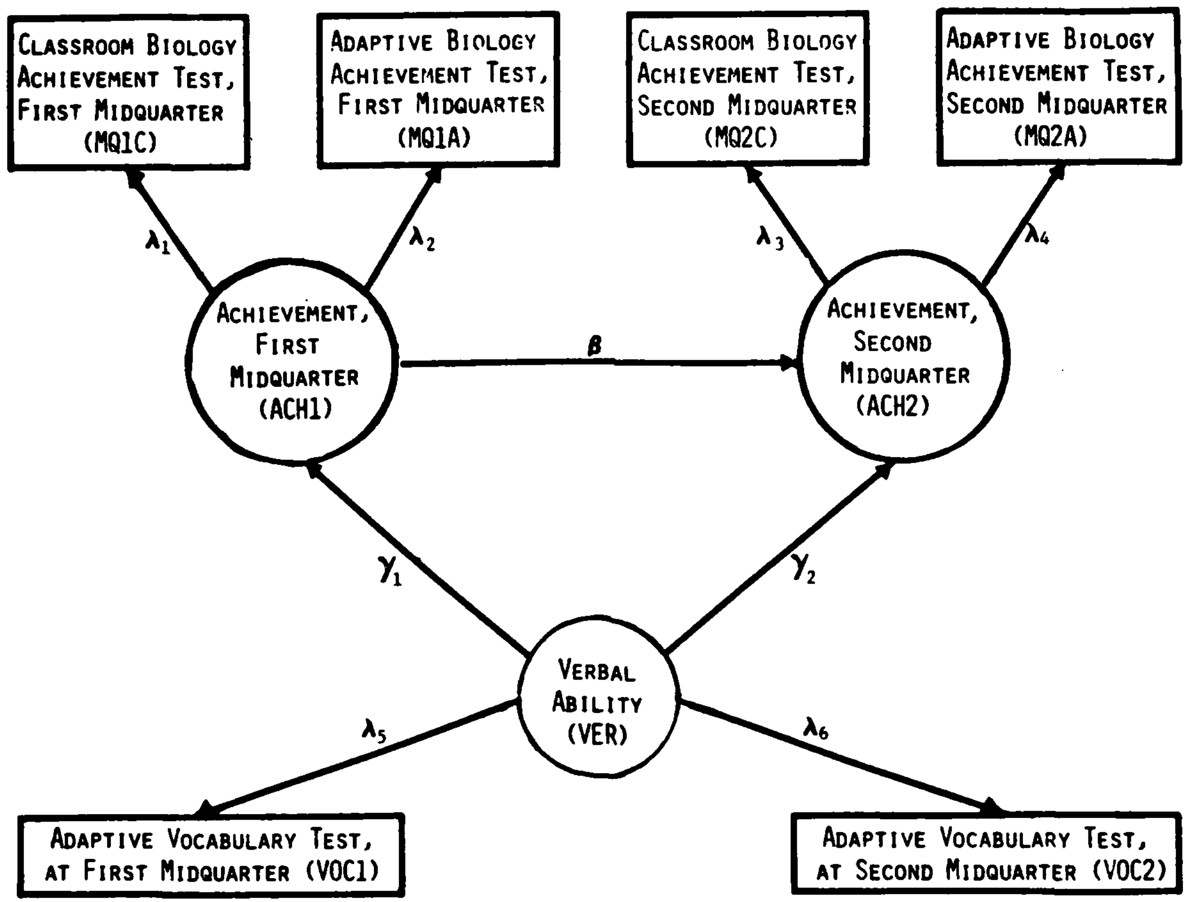

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Adaptive Biology Achievement Test, First Midquarter (MQ1A)
Classroom Biology Achievement Test, Second Midquarter (MQ2C)
Adaptive Biology Achievement Test, Second Midquarter (MQ2A)
λ1
λ2
λ3
λ4
Achievement, First Midquarter (ACH1)
β
Achievement, Second Midquarter (ACH2)
γ1
γ2
Verbal Ability (VER)
λ5
λ6
Adaptive Vocabulary Test, at First Midquarter (VOC1)
Adaptive Vocabulary Test, at Second Midquarter (VOC2)

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